

Serrated Kiln Sticks and Top Load Substantially Reduce Warp In Southern Pine Studs Dried at 240°F

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Abstract

Sharply toothed aluminum kiln sticks pressed into 2 by 4's cut from veneer cores, with a clamping force of 50 to 200 pounds per stick-pair per stud, significantly reduced warp from that observed in matched studs stacked on smooth sticks with a top load of 10 pounds per stick-pair per stud. When dried in 24 hours to an average MC of 8.1 percent (standard deviation of 2.3 percentage points), studs pressed between serrated sticks had crook (0.13 inch), bow (0.21 inch), and twist (0.16 inch) averaging only 54, 70, and 46 percent of that observed in studs secured between smooth aluminum sticks. For studs gripped between serrated sticks, maximum observed crook (0.33 inch), bow (0.72 inch), and twist (0.68 inch) were only 28, 53, and 44 percent of that noted in studs stacked on smooth sticks. All studs were surfaced on two sides to a uniform thickness of 1.78 inches prior to drying. Stud edges were left rough so they had width variation normal for the studs from the mill sampled; average width was 4.2 inches. To exploit the idea of heavy top load combined with serrated sticks, a kiln design is proposed.

SINCE 1963, the Southern Forest Experiment Station's laboratory in Pineville, Louisiana, has been continuously studying the kiln-drying of southern pine lumber cut from small trees and veneer cores. The primary objective of this research has been to

diminish warp when such lumber is dried to moisture contents (MCs) (8 to 10 percent) at which most of it will serve in the heated and air-conditioned homes of customers. A secondary objective has been to diminish time in kiln. It has also been hoped that the research would stimulate kiln designs less demanding in energy per thousand board feet dried than the southern pine kilns in wide use in 1963.

It was early observed that if southern pine lumber were dried at temperatures above the boiling point of water, kiln time to 8- to 10-percent MC could be reduced from several days to about 12 hours per inch of lumber thickness; moreover, warp in lumber dried under mechanical restraint at such temperatures (e.g., 240°F) was significantly reduced.¹

During these years, the industry has widely accepted the idea of drying southern pine at temperatures above the boiling point of water, and

¹Koch, P. 1971. Process for straightening and drying southern pine 2 by 4's in 24 hours. *Forest Prod. J.* 21(5):17-24.

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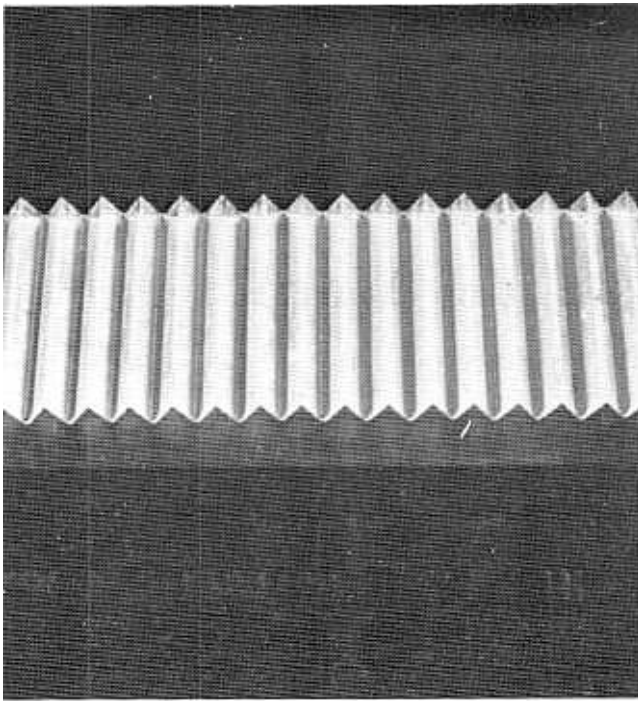


Figure 1. — Detail of 1.50- by .75-inch kiln stick 28 inches long, machined with sharp serrations designed for indentation into flat surfaces of random-width lumber, providing restraint against crook. Serrations are 3/16-inch deep, with pitch of 1/4-inch; included angle of each tooth is 60 degrees.

most kilns sold today in the South operate at such temperatures.

Mechanical restraint of lumber against crook, bow, and twist has not been accepted widely, however. A main obstacle is the difficulty of applying such restraint in a dry kiln. It is true that heavy top loads on kiln stacks, e.g., thick concrete slabs, have been successfully used during the last several years by a few lumber companies and custom kiln-drying companies in the United States and in Australia. No doubt

numerous firms elsewhere in the world have also applied top loads to achieve various desired specific pressures in the upper courses of kiln loads.

Such top loads are quite effective in reducing bow and twist in southern pine dried at 240°F, but are much less effective in controlling crook. Since crook causes more value loss in southern pine lumber than either bow or twist, it would seem that a better mechanism for restraint against crook is required.

Another series of experiments aimed at reduction of crook yielded mechanisms² that were effective but costly; more important, they required that green lumber be precisely sized to width before admission to the kiln apparatus.

The experiment reported here describes efforts to combine a heavy top load (to control bow and twist) with a new design of sharply serrated aluminum kiln sticks (Figs. 1 and 2) to prevent crook in thickened studs not previously sized accurately in width.

Green southern pine studs weigh about 22 pounds each. In the second or third course down from the top of a kiln charge with no top load (at which level warp is usually severe) the force on each stick pair per stud is therefore about 10 pounds. The study compared crook (and bow and twist) observed in lumber gripped with smooth sticks at such low force with crook observed with serrated sticks under a heavy top load. An additional purpose was to suggest a kiln design to exploit the idea if the top-loaded serrated sticks proved successful.

Procedure

In each kiln load, warp in a single layer of six studs conventionally stacked on smooth aluminum sticks (1.50 by .75 by 28 inches) with a uniformly distributed top load was compared with warp in another single layer of six matched studs forcefully gripped

²Koch, P. 1974. Trials of prototype roll-feed, high-temperature dryer for 8/4 southern pine. *Forest Prod. J.* 24(5):24-28.

Figure 2. — In one treatment, top and bottom serrated sticks were screwed to a pair of plywood panels so that the sticks on each panel were fixed in relation to each other.



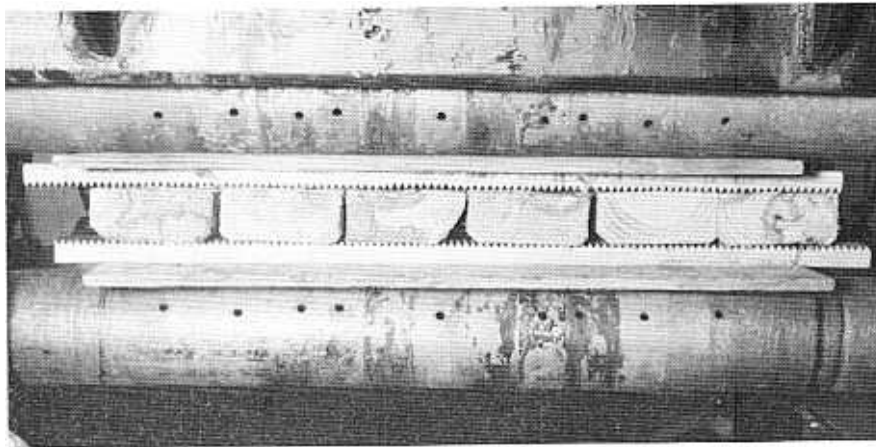


Figure 3. — In each kiln load, six random-width (i.e., not width-sized) S2S studs were dried between serrated sticks. Pressure was applied to this lumber layer and its serrated sticks by pressing the top roll case down onto the lower roll case. The rolls were stationary (not revolving), and the mechanism was simply used as a press.

between five pairs of serrated sticks (Fig. 3). The conventionally stickered studs were placed on the top of the roll mechanism shown in Figure 3, and the entire assembly was wheeled into the kiln.

Twenty kiln loads were dried, for a total of 240 studs; factors were as follows:

Treatments, general:

1) Conventionally stickered between five pairs of smooth sticks with uniformly distributed top load of 50 pounds per stud or 10 pounds per stick pair per stud.

2) Squeezed between five pairs of serrated sticks with the four arrangements described below.

Treatments in serrated stick arrangements (Fig. 3):

1) Loose: Sticks placed individually, not secured to backing boards.

2) Fixed: Sticks screwed to sheets of 1/2-inch plywood to prevent motion relative to one another (Fig. 2).

Force squeezing pairs of serrated sticks together:

1) High: 6,000 pounds total or about 1,200 pounds per pair of sticks, or about 200 pounds per stick pair per stud.

2) Low: 1,500 pounds total or about 300 pounds per pair of sticks or about 50 pounds per stick pair per stud.

Boards per kiln load: Six conventionally stickered and six dried between serrated sticks.

Replications of loads: Five

The studs, purchased from a plywood plant in north-central Louisiana, were cut from southern pine veneer cores. At the laboratory, all were trimmed to 100-inch length and surfaced S2S to 1.78-inch thickness. Since edges were left rough, the pieces had the width variation normal for the stud mill; average width was 4.20 inches. Before each load replication, studs were measured green for weight, length, width, thickness, twist, bow, and crook.

For each load replication, the studs were charged into a cold kiln, which was then heated to 240°F dry-bulb temperature with 160°F wet-bulb temperature and held for 21 hours after startup; the load was then steamed for 3 hours at 195°F/185°F. At the end of the 24-hour period the load was discharged and each stud

Table 1 PROPERTIES OF GREEN STUDS.¹

Property	Mean	Standard deviation	Maximum	Minimum
MC (%)	77.7	31.87	170.9	30.7
Weight (lb.)	21.9	3.16	28.6	15.4
Length (in.)	100.0	.110	100.07	99.60
Width (in.)	4.20	.011	4.22	4.16
Thickness (in.)	1.79	.016	1.79	1.72
Crook (in.)	.083	.036	.19	.05
Bow (in.)	.115	.046	.23	.05
Twist (in.)	.082	.024	.16	.05
Specific gravity ²	.475	.056	.58	.36

¹These properties did not vary significantly among treatments.

²Basis of oven-dry weight and green volume.

measured immediately for weight, dimensions, and warp. One-inch cross-sectional slices were taken at quarter points of each stud to permit computation of ending MC and specific gravity.

Results

The green studs averaged 77.7 percent in MC and 21.9 pounds in weight (Table 1). Crook, bow, and twist, when green, averaged 0.08, 0.12, and 0.08 inch. Specific gravity was 0.47 (based on green volume and oven-dry weight).

Dry studs averaged 8.1 percent in MC, with range from 0.7 to 14.6 percent and standard deviation of 2.3 percent. Average stud weight on discharge was 13.5 pounds (Table 2), with range from 10.3 to 20.0 pounds. Width and thickness shrinkage did not differ by treatment and can be summarized as follows:

Shrinkage

	Width	Thickness
	----- Inch -----	
Average	0.12	0.08
Maximum	.21	.13
Standard deviation	.03	.02

Length shrinkage for the studs piled on smooth sticks (0.11 inch) was greater than that for studs piled on serrated sticks (0.08); this difference in length

shrinkage is probably attributable to the greater degree of crook observed in studs piled on smooth sticks.

Warp in the dry studs varied significantly (0.05 level) with treatment. Studs pressed between serrated sticks had significantly less crook, bow, and twist than those conventionally stickered on smooth sticks; the higher pressure was not more effective in reduction of crook, bow, or twist than the lower level, however. Covariance analysis of crook when green and when dry supported these conclusions based on dry warp alone. Loose serrated sticks were about as effective as fixed serrated sticks in reducing crook.

The data can be summarized by the following averages (with maximum observed value in parentheses alongside each average, and standard deviation in italics below):

Treatment	Crook	Bow	Twist
	----- Inch -----		
Conventionally stickered	0.24(1.20) <i>0.173</i>	0.30(1.36) <i>0.204</i>	0.35(1.55) <i>0.293</i>
Pressed between serrated sticks			
High pressure, loose	.13(.25) <i>.049</i>	.17(.64) <i>.109</i>	.13(.35) <i>.073</i>
High pressure, fixed	.12(.24) <i>.037</i>	.21(.48) <i>.089</i>	.19(.50) <i>.118</i>
Low pressure, loose	.16(.33) <i>.073</i>	.24(.72) <i>.137</i>	.19(.68) <i>.161</i>
Low pressure, fixed	.12(.27) <i>.059</i>	.20(.52) <i>.117</i>	.15(.28) <i>.062</i>

In brief, for studs pressed between serrated sticks, the crook (0.13 inch), bow (0.21 inch), and twist (0.16 inch) averaged only 54, 70, and 46 percent of that for studs between smooth sticks. For studs gripped between serrated sticks, maximum observed crook (0.33 inch), bow (0.72 inch), and twist (0.68 inch) were only 28, 53, and 44 percent of that noted in studs stacked on smooth sticks.

Lumber damage from serrated sticks—The serrated sticks effectively reduced crook because they were indented into both surfaces of each stud. These indentations remained visible after the studs were discharged from the kiln (Fig. 4). Planing to standard 1.5-inch thickness and 3.5-inch width removed all traces of these indentations, so that stud surfaces were indistinguishable from those of studs dried on smooth sticks.

Discussion of Additional Work Needed and of Design Features of Proposed Commercial Kiln

The results of the experiment were positive and suggest some thoughts on steps needed to commercialize the concept.

The load per stick pair per stud crossing at the bottom of a 10-foot-high kiln stack is about 220 pounds—assuming no top load. With the addition of a top load of 100 pounds per stick pair per stud crossing, the total would vary from 100 pounds in the top course to 320 pounds in the bottom course, yielding an average of 210 pounds. A top load of 100 pounds per stick pair per stud could be obtained with a concrete

Table 2. — PROPERTIES OF DRY STUDS.

Property and treatment	Mean	Standard deviation	Maximum	Minimum
MC (%)				
Pressed between serrated sticks				
High-pressure, loose	9.0	1.93	14.6	6.4
High-pressure, fixed	8.7	2.05	13.3	5.8
Low-pressure, loose	8.0	2.43	12.7	.7
Low-pressure, fixed	8.3	2.71	14.5	1.7
Conventionally stickered	7.7	2.23	14.0	1.1
Weight (lb.)				
Pressed between serrated sticks				
High-pressure, loose	13.5	1.85	17.4	10.4
High-pressure, fixed	13.1	1.35	16.1	10.9
Low-pressure, loose	13.8	1.67	16.6	10.3
Low-pressure, fixed	13.7	1.89	19.9	11.4
Conventionally stickered	13.5	1.80	20.0	10.5
Length (in.)				
Pressed between serrated sticks				
High-pressure, loose	99.9	.06	100.0	99.9
High-pressure, fixed	99.9	.06	100.0	99.8
Low-pressure, loose	99.9	.08	100.1	99.7
Low-pressure, fixed	99.9	.07	100.0	99.7
Conventionally stickered	99.9	.11	100.0	99.6
Width (in.)				
Pressed between serrated sticks				
High-pressure, loose	4.08	.027	4.13	4.04
High-pressure, fixed	4.09	.024	4.12	4.02
Low-pressure, loose	4.08	.042	4.15	4.00
Low-pressure, fixed	4.08	.037	4.15	4.00
Conventionally stickered	4.07	.028	4.15	4.00
Thickness (in.)				
Pressed between serrated sticks				
High-pressure, loose	1.68	.025	1.72	1.61
High-pressure, fixed	1.68	.017	1.72	1.65
Low-pressure, loose	1.69	.026	1.75	1.63
Low-pressure, fixed	1.69	.022	1.74	1.64
Conventionally stickered	1.68	.025	1.74	1.63

slab 11 inches thick. From observations during the study, splitting of studs from 320 pounds of load per stick pair per stud crossing does not appear likely.

Needed Research

Unstacking of lumber gripped on two sides by serrated sticks poses some problems in separating sticks from lumber; possibly only one surface of each stick needs to be serrated. This facet of the problem needs elucidation. Also to be determined are the pitch and minimum depth of serrations required for effective crook restraint. Unless sticks seat uniformly on each course and remain level, twist in individual boards will result. Satisfactory performance of serrated sticks in a 10-foot-high load needs confirmation.

One might speculate that serrated sticks should only be employed in upper courses; observations of southern pine stacked on smooth sticks indicates that crook in lower courses, while less than in top courses, is still substantial. For this reason, it is proposed that serrated sticks be used throughout the pile.

Proposed Kiln Design

A double-track tunnel dryer is proposed in which the heated zone would be about 72 feet long. Wheeled

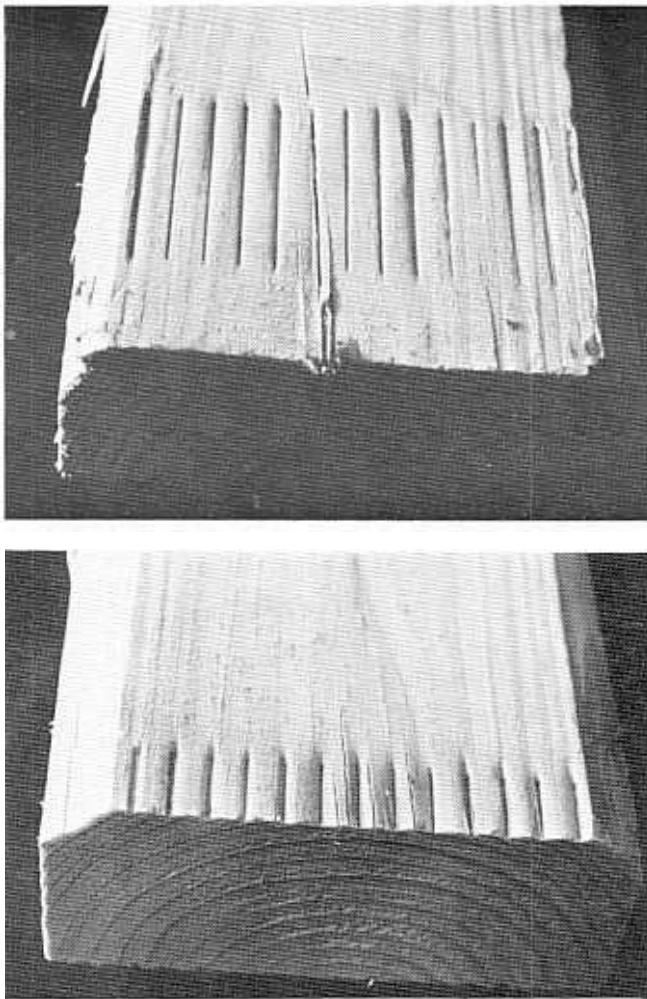


Figure 4. — (Top) Serrated sticks caused visible indentations in the lumber. (Bottom) The upper of the two pressure levels evaluated caused indentations in softer studs measuring about .03 inch deep.

kiln cars of random-width lumber, of uniform length and thickness (controlled by surfacing one side to 1-3/4 inches), would travel through this tunnel in train fashion. Transit time through the tunnel would be 24 hours, of which the initial 21 hours would be in a zone held at a dry-bulb temperature of 240°F with 80° wet-bulb depression; the final 3 hours would be in a zone maintained at a dry-bulb temperature of 195°F with 10° wet-bulb depression. Cross-circulation air velocity throughout the tunnel would be 700 feet per minute (or higher), with air direction reversed in adjacent 16-foot lengths of the tunnel.

Loads would measure 8 feet wide and 10 feet high, so that a load 8 feet long would contain 1,200 studs or 6,400 board feet. Holding capacity in the 72-foot-long heated zone (and outturn per 24 hours) would therefore be 18 kiln cars or 115,200 board feet. With such an arrangement, the double string of kiln cars would be advanced 3 feet per hour.

Eight-foot metal kiln sticks 1.5 inches wide and 0.75 inches thick, serrated on one surface (possibly on both), would be placed at 2-foot intervals between lumber courses. An 18-car charge of studs would therefore call for 4,500 sticks in the kiln with at least double this number of sticks additionally required for loads awaiting kiln entry and for loads in the cooling shed awaiting unstacking.

To achieve a top load of 100 pounds per stick-stud crossing, a top load of 9,000 pounds would be required for a kiln car of studs. It is proposed that this be accomplished with a 9-foot-wide, caterpillar-like, endless bed comprised of concrete slabs 9 feet long, 4-1/4 feet wide, and about 11 inches deep. Each end of each concrete slab would carry a pair of wheels designed to ride steel rails positioned on each side of, and just below, the top of 10-foot-high kiln loads. With lumber in the kiln, the concrete slabs would ride the top of the loads; with no kiln stack present, the slabs would be carried by the steel rails. Each track of the double-track kiln would be provided with such a top-load system of powered headshaft, tailshaft, and endless bed—all contained within the heated portion of the kiln below the unidirectional cross-circulating fans.

Energy Aspects

Thermal efficiency is a major advantage of the design proposed. In a conventional batch kiln, substantial heat (and time as well) is wasted during the heatup period. In the proposed tunnel dryer, both zones operate at constant temperatures; kiln warmup losses are thereby eliminated. Moreover, the water vapor evaporated in the initial drying zone can be utilized to humidify the conditioning zone, with consequent saving of heat energy. It would be possible to charge and discharge kiln cars through thermal locks to further minimize thermal losses.

Also, the fan-reversing mechanisms usual in conventional batch kilns should not be necessary in the proposed tunnel dryer, because air could be circulated in alternate directions in successive 20-foot zones of the dryer. Fans that move air in only one direction can be designed to consume less energy than fans that must reverse.

Conclusion

Use of serrated sticks and substantial top loads in a 240° kiln seems to have merit; crook in southern pine studs so dried to 8.1 percent MC was about half that observed in similar studs dried at high temperature on smooth sticks. A tunnel dryer designed for top-loaded kiln cars and serrated sticks should have good thermal and mechanical efficiency. Construction costs should not be excessive, although cost of sticks would be several times that of conventional smooth wood kiln sticks. If kiln sticks are serrated on both sides, unstacking equipment will have to provide special mechanisms to separate sticks from studs; possibly, only one surface of the sticks needs serration. This remains to be determined by further research.

Drawings for a commercial kiln utilizing the concept are in preparation.